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Short communication

Does having a drink help you think? 6–7-Year-old children show improvements in cognitive performance from baseline to test after having a drink of water

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ABSTRACT

Little research has examined the effect of water consumption on cognition in children. We examined whether drinking water improves performance from baseline to test in twenty-three 6–7-year-old children. There were significant interactions between time of test and water group (water/no water), with improvements in the water group on thirst and happiness ratings, visual attention and visual search, but not visual memory or visuomotor performance. These results indicate that even under conditions of mild dehydration, not as a result of exercise, intentional water deprivation or heat exposure, children's cognitive performance can be improved by having a drink of water.

Introduction

There are well-established links between dehydration and cognition in adults. Dehydration has been shown to impact negatively on attention (Suhr, Hall, Patterson, & Niinistö, 2004), short-term memory (Cian et al., 2000; Gopinathan, Pichan, & Sharma, 1988; Suhr et al., 2004) and psychomotor tasks (Gopinathan et al., 1988; Suhr et al., 2004). Even mild dehydration of 1% has been shown to negatively affect performance on a serial addition task (Gopinathan et al., 1988), and the evidence suggests there is a dose–response relationship between dehydration and cognition (Lieberman, 2007). In these studies, dehydration is induced by means of heat exposure, fluid restriction, physical activity, or a combination of these factors.

Dehydration may also have negative effects on cognition in children. Bar-David, Urkin, and Kozminsky (2005) studied children who were dehydrated as a result of living in a hot climate (Israel) and separated them into a hydrated or dehydrated group on the basis of their naturally occurring hydration status assessed by urine osmality. The dehydrated group performed significantly worse on tests of digit span, and showed trends towards poorer performance on semantic flexibility and pattern identification. Thus, this study suggests that children's cognitive performance is affected by dehydration in a similar manner to that observed in adults.

There is evidence to suggest that many school children are dehydrated (D'Anci, Constant, & Rosenberg, 2006; Fadda et al., 2008; Kaushik, Mullee, Bryant, & Hill, 2007), and recent research has suggested that having a drink of water can improve cognitive performance in children. Edmonds and Burford (2009) showed that drinking water had a positive effect on cognitive performance in children aged 7–9 years. Children who drank additional water performed better on a range of cognitive tests compared to children who did not have an additional drink and performance was better on a test of visual attention (letter cancellation) and two tests of visual memory (spot the difference tasks). Fadda et al. (2008) also manipulated the availability of water to a large group of Italian children and found associations between hydration status and digit span.

The aims of the present study were three-fold. Firstly, this study aimed to confirm existing findings that suggest that a drink of water affects the cognitive performance of children in their natural hydration state, who have not been purposely dehydrated for the purposes of study. The second aim was to test children both before and after water consumption in order to demonstrate improvement in cognitive function relative to baseline, as well as relative to the control group. The third aim was to introduce some additional tests of cognition and mood. The hypothesis was that the performance of the group of children who had a drink of water would improve from baseline to test, whilst the performance of the control group would not improve.

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Method

Participants

Twenty-three children participated in the study (14 girls). They were aged between 6 years 8 months and 7 years 8 months ($M = 7$ years 3 months). All children from one class were invited to participate and parental consent was obtained. There was one child whose parents did not want him to participate and this child did not take part.

There were 11 children in the group that received water (7 girls; water group) and 12 children in the control group that did not receive water (7 girls; no water group). There were broadly even numbers of children with Special Educational Needs (SEN) and English as an additional language (EAL) in the two groups. Two children in the water group had SEN and there was 1 child with SEN in the no water group. Three children in the water group had EAL, with 4 children with EAL in the no water group. In terms of ethnicity, 18 children were White and 5 were Black African. The study was approved by the University of East London, School of Psychology ethics board.

Measures

Rating scales

Subjective thirst. This was measured using a rating scale that required children to mark a line on a scale of 1–10 to indicate thirst. The thirstiest score (10) was accompanied by the statement, "I feel very thirsty" and a picture of a woman drinking, whilst the opposite end of the scale (1) was accompanied by the statement, "I am not thirsty at all" and a thirsty looking cartoon smiley. The same rating scale was used at baseline and test.

Happiness scale. Subjective ratings of mood were used to assess happiness. Children were asked to circle one of five faces that varied in the size of their smile or frown to indicate how happy they were. They were accompanied by text explaining the emotion. These descriptions ranged from "I feel very happy" (very smiley face; score = 5), through, "I feel happy", "I feel OK", "I feel sad", or "I feel very sad" (very sad face; score = 1). The same rating scale was used at baseline and test.

Cognitive tasks

The cognitive tasks were selected because prior research has shown that performance requiring these cognitive processes has been affected by either drinking water, or by hydration status. Tasks employed by Edmonds and Burford (2009) were used (visual memory, visual search, visuomotor performance). A visual attention task was also included as prior research in adults indicates that perceptual discrimination and attention are affected by dehydration (Suhr et al., 2004).

Visual attention. This was assessed using spot the difference tests. Two cartoon pictures were simultaneously presented and children were asked to identify differences (total differences = 10). Differences were marked on the right picture. One minute was allowed to identify and mark differences. Different pairs were used at baseline and test, and the presentation of these was counterbalanced over groups and time points.

Visual memory. This task also adopted a spot the difference approach. However, in this case, original and test images could not be compared. Children were shown the first picture for 1 min, immediately followed by a blank page, which was viewed for 5 s. The blank page was inserted in order to avoid visual pop-out of differences due to apparent motion effects (Pashler, 1988). The test picture was viewed for 1 min and a maximum of 3 differences were identified by marking on the test picture. Different pictures were used at baseline and test, and the presentation of these was counterbalanced over groups and time points.

Visual search. A letter cancellation task assessed visual search. Children were presented with a 17 cm × 12 cm rectangle in which target (P, $n = 40$) and distractor letters (q, $n = 40$) were distributed randomly. In 1 min, children were required to cross through as many targets as they could, whilst ignoring distractors. The maximum score was 40; each target correctly identified scored 1 point, whilst 1 point was deducted for each incorrectly identified distractor.

Visuomotor performance. This was assessed using a line tracking task. Children drew a line between two curving parallel lines as fast as possible. The time limit was 20 s. A score of 10 was awarded if no errors were made and one point was deducted for every time a participant made an error by drawing outside the guiding lines. The same measure was used at baseline and test.

Procedure

Children were tested in a whole class group, but they completed the tasks individually, sitting at their usual classroom desk, with a small screen erected between participants to prevent conferring or copying. These screens are frequently used in classroom assessment in the UK and were familiar to our sample. There was a break of approximately 1 min between each cognitive task. Before each task, the children were given a brief description of its content and were told how long they would have to complete it. Testing commenced at the beginning of the school day, at approximately 9.30 a.m. The cognitive assessment took approximately 20 min at each time point. Parallel forms of visual memory and visual attention were employed in order to avoid practice effects. A 2 × 2 latin square design was used for counterbalancing. The same version of thirst and happiness scales, visual search and visuomotor precision were used at baseline and test.

Approximately 40 min after completion of baseline testing, children in the no water group left the room. Children in the water group remained and were given a 500 ml bottle of water and asked to drink as much as they wanted. The no water group was not aware that the other group had been given a drink. The test session was conducted approximately 45 min after water consumption. On completion, children were de-briefed and thanked for their involvement.

Statistical analysis

For the most part, the statistical analyses used mixed analysis of variance (ANOVA) to compare baseline and test measures in the water and no water groups. In the first instance, this ANOVA design considered whether feelings of subjective thirst decreased for children in the water group. If consuming water results in decreased thirst, this supports the argument that children were initially dehydrated and that water consumption addressed this dehydration. Scores on the happiness scale were then compared in order to examine whether water consumption affected subjective feelings of happiness. This statistical design was then applied to each cognitive task to examine whether water consumption improved task performance in the manner suggested by earlier studies (Edmonds & Burford, 2009). When significant interactions were reported, follow-up tests were conducted comparing scores at baseline and test separately for the water and no water groups. The Bonferroni correction for multiple tests was employed and the alpha level was set at 0.025 (0.05/2 follow-up tests).

We then assessed whether initial thirst moderated the relationship between water consumption and task performance. Rogers, Kainth, and Smit (2001) reported that having a drink of water improved the performance of adults who were thirsty, but not that of adults who were not thirsty. Although a recent study did not show such a relationship in children (Edmonds & Burford, 2009), we formally tested this in our study. We conducted a series of ANOVAs in which group differences (water vs. no water group) in difference scores (test–baseline) were examined, whilst covarying baseline thirst. If thirst moderates the water consumption effect in children in a manner similar to that observed in adults, it would be expected that the covariate would have a significant effect and would alter the effect of water consumption on task performance.

The final set of analyses were exploratory and assessed whether changes in subjective happiness ratings underlie the water consumption effect. There are well-established effects of mood on cognitive performance (Storbeck & Clore, 2009) and if mood improves with access to water, it may be that improvements in mood underlie effects on cognition attributed to water consumption. We conducted a series of ANOVAs in which group differences (water vs. no water group) on the outcome measures were assessed, whilst covarying the happiness difference score (test–baseline). If changes in mood underlie the water consumption effect, it would be expected that the effect of the covariate would be statistically significant and that it would influence the expected group differences (water vs. no water).

Results

The classroom temperature on the day of testing was 20 °C. All children completed all tasks and there were no missing data. Mean and SD scores for all outcome measures at baseline and test in the water and no water groups are shown in Table 1.

Water consumption and subjective thirst ratings. Children in the water group drank an average of 409.1 ml water (SD = 130.19; range 150–500 ml). Overall children reported higher subjective thirst at baseline compared to test, $F(1,21) = 24.08$, $p < 0.001$. There were no overall differences between groups, $F(1,21) < 1$. However, more importantly, there was a significant interaction between time of test and group, $F(1,21) = 17.34$, $p < 0.001$, with ratings of thirst decreasing more between baseline and test for children who consumed water, $t(10) = 5.37$, $p < 0.001$, compared to those who did not, $t(11) = 0.66$, $p = 0.524$. These results support the argument that drinking water served to decrease subjective thirst.

Happiness scale. There was a main effect of water group on happiness ratings, with scores lower in the group that did not receive water, $F(1,21) = 4.43$, $p = 0.048$. It is likely that this difference in overall mean scores is due to a higher happiness rating for the no water group at baseline. There was a significant interaction between water group and time of test, $F(1,21) = 7.11$, $p = 0.014$, with the water group rating their happiness 0.73 points higher at test than at baseline, whilst the no water group's decreased by 0.58 points. However, follow up *t*-tests revealed that the water group's reduction in ratings did not quite reach statistical significance at the corrected level, $t(10) = 2.39$, $p = 0.038$. Neither was the difference statistically significant in the no water group, $t(11) = 1.54$, $p = 0.152$. There was no main effect of time of test on happiness ratings, $F(1,21) < 1$.

Cognitive tasks

Visual attention. Children identified more differences between cartoons at test than at baseline, $F(1,21) = 14.0$, $p = 0.001$. This main effect of time of test should be interpreted in the light of a significant interaction between water group and time of test, $F(1,21) = 11.42$, $p = 0.003$. Follow-up tests show that improvement in scores was restricted to children in the water group, $t(10) = 4.22$, $p = 0.002$, with no significant change in the no water group, $t(11) = 0.32$, $p = 0.754$. There was no main effect of water group on this measure, $F(1,21) = 2.46$, $p = 0.132$.

Visual memory. In contrast, performance on the visual memory task, that also employed a spot the difference approach, was not affected by time of test, $F(1,21) = 2.10$, $p = 0.162$, nor by group assignment, $F(1,21) = 2.65$, $p = 0.119$, nor was the interaction significant, $F(1,21) < 1$. It may be that the children found this task too easy; scores in all four conditions were close to ceiling.

Visual search. Performance was better at test than baseline, $F(1,21) = 5.84$, $p = 0.025$. This effect was moderated by whether the children had water, $F(1,21) = 10.82$, $p = 0.003$, with children in the water group showing a statistically significant improvement at the corrected level at test, $t(10) = 2.81$, $p = 0.019$. Children in the control group did not improve, $t(11) = 1.90$, $p = 0.085$. The main effect of water group was not statistically significant, $F(1,21) < 1$.

Visuomotor performance. Scores improved after having a drink of water, with the interaction approaching significance, $F(1,21) = 4.20$, $p = 0.053$. Because an interaction was predicted, follow up *t*-tests were conducted to explore this further. However, there were no significant differences between performance at baseline and test in either the water group, $t(10) = 1.31$, $p = .221$, or no water group, $t(11) = 1.92$, $p = 0.082$. There were no main effects of either time of test, $F(1,21) < 1$, or group, $F(1,21) < 1$.

Was there a moderating effect of thirst? ANOVAs were conducted in which group differences (water vs. no water group) were examined on difference scores (test–baseline), whilst covarying baseline thirst. The results were consistent with those found for the main analyses, with significant interactions between water group and time of test found for happiness ratings, $F(1,20) = 7.50$, $p = .013$; visual attention, $F(1,20) = 10.87$, $p = 0.004$, and visual search, $F(1,20) = 10.65$, $p = 0.004$; but not in the case of visual memory, $F(1,20) < 1$, or visuomotor performance, $F(1,20) = 3.99$, $p = 0.060$. In no case was the thirst covariate statistically significant. These findings suggest that thirst did not moderate the relationship between drinking water and improved performance in this study.

Was there a moderating effect of mood? Our data suggest that subjective ratings of happiness improved in children who had a drink of water, whilst they did not improve in those who did not have a drink. Thus, it is possible that the water consumption effect

Table 1
Means and SDs on all cognitive tasks for water and no water group at baseline and test.

Task	Water group				No water group			
	Baseline		Test		Baseline		Test	
	M	SD	*M*	SD	*M*	SD	*M*	SD
Thirst ratings	4.55	2.42	2.45	2.84	6.25	3.57	5.83	3.71
Happiness ratings	3.18	0.98	3.91	0.70	4.50	0.67	3.92	1.31
Visual attention	5.18	1.66	6.82	1.94	5.08	1.00	5.17	1.03
Visual memory	2.45	0.52	2.82	0.40	2.33	0.65	2.42	0.51
Visual search	33.55	6.31	39.0	1.34	37.25	3.52	36.42	3.15
Visuomotor precision	8.09	1.81	8.82	2.04	9.08	1.16	8.58	1.24

results from changes in mood, which affected cognitive performance. We conducted a series of exploratory analyses to explore this. ANOVAs were conducted that assessed group differences (water vs. no water group) on the outcome measures difference scores (test–baseline), whilst covarying the happiness difference score. The results supported those found for the main analyses, with significant interactions between water group and time of test found for thirst ratings, $F(1,20) = 7.16$, $p < .001$; visual attention, $F(1,20) = 13.99$, $p = 0.001$; visual search, $F(1,20) = 10.30$, $p = 0.004$; but not in the case of visual memory, $F(1,20) = 0.869$, $p = 0.362$, or visuomotor performance, $F(1,20) = 2.45$, $p = 0.134$. In no case was the covariate of happiness statistically significant. These findings suggest that the water consumption effect observed in the present study did not result from changes in mood, although it should be noted that these analyses were exploratory and replication is necessary.

Discussion

The results of the present study suggest that consuming a drink of water has positive effects on cognitive performance in children. All water group effects were moderated by the time of test (baseline vs. test), thus suggesting that improvements on visual search and visual attention tasks that were observed at test relative to baseline were a result of water consumption. Performance on some measures showed improvement between baseline and test (visual attention and visual search) and it is not surprising that some tests are subject to practice effects.

Our findings that having a drink of water improved performance on tests of visual attention and visual search are consistent with the literature. Edmonds and Burford (2009) also reported an effect of water consumption on a visual search task. Studies examining the relation between hydration status and cognitive performance have also reported effects on visual tasks, both in children (Bar-David et al., 2005) and in adults (Suhr et al., 2004). It should be noted that in a recent paper Benton and Burgess (2009) found that water consumption did not affect performance on a sustained attention task, suggesting that different aspects of attention may be selectively affected by water consumption.

Although previous research has found that drinking water improved children's performance on a task that assessed visual memory (Edmonds & Burford, 2009), we did not replicate this finding. This is likely to have occurred because the task used was too simple. In a bid to make this memory task age appropriate, we selected images with fewer differences in order to reduce the memory load. Unfortunately, this resulted in performance close to ceiling.

In the case of mood, although there was a statistically significant interaction between water group and time of test on the subjective assessment of happiness, follow-up tests did not reach significance. Therefore, strong conclusions concerning the effect of drinking water on mood should not be made on the basis of these findings. Our finding that water consumption increased happiness ratings is novel, but not unsurprising; addressing the physiological feeling of thirst is likely to be satisfying. Whilst there are well-established effects of mood on cognition (Storbeck & Clore, 2009), exploratory analyses suggested that the effect of water consumption on cognition did not result from changes in mood and the subsequent effect of mood on cognitive performance. These exploratory analyses need replication.

One factor that should be considered is whether children's performance may have been affected by the demand characteristics of the study. We think that this explanation is unlikely because children in the two groups were not aware that they were being treated differently. In future studies we plan to address this issue formally, perhaps by including a measure of effort or motivation to test whether children given a drink of water group try harder than children who are not given a drink.

Further research should attempt to further explicate the cognitive processes affected by water consumption and consider the parameters of the effects reported here. For example, it could consider the optimal interval between water consumption and test performance and the optimal amount of water necessary to improve task performance. It should also consider whether these factors are affected by age; children of different ages, and thus also diverse body sizes, will differ in the amount of liquid necessary for optimal hydration. It should be noted that the suitable daily allowance of fluid is the subject of deliberation (Valtin, 2002). Future research should also attempt to elucidate the mechanisms underlying the effect of hydration on cognition.

In conclusion, our results indicate that even under conditions of mild dehydration, not as a result of exercise, intentional water deprivation or heat exposure, children's cognitive performance can be improved by having a drink of water. Further research is necessary both to investigate the parameters of the effect of water consumption on cognition and to explore potential mechanisms.

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